Visualization by People without Vision

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Abstract

Prototypes of two direct audio/tactile access methods are demonstrated that allow people with print disabilities to "see" diagrams, maps, charts, and other graphically-displayed information. All methods require that labels or other identifying information be available for each important object in a figure. In web applications, this additional information is accessed by exercising a link associated with an object. People with severe visual disabilities may need a tactile image mounted on a touch screen to access object-related information. It is expected that recently-introduced force feedback "haptic mice" may soon provide easy haptic access to the objects as well. The critical factor that ensures accessibility is availability of information about all important objects, since there is currently no way to transform any but the simplest purely visual graphic information into audio or tactile/haptic information that is easily understandable. These requirements, which also ensure good searchability, should influence development of future data structures and visualization displays.

Introduction

Blind people have good access to many computer applications through use of screen reader software and either a speech synthesizer or a braille display. Speech technologies have proven to be useful to many people who are not blind. Many people suffer from visual dyslexia sufficiently that they can understand virtually nothing in prrint even though they may have perfect vision. It is also well understood that a substantial fraction of people are "audio learners" who understand what they hear better than what they see. All these people benefit from availability of speech and other audio output instead of or in addition to the normal visual display.

However speech or other alternate access is presently limited largely to unformatted text. The mission of the Science Access Project (SAP) is to develop technologies that permit non-visual access to more complex electronic information. Until recently this research has concentrated largely on access to tables, math equations and other character-based information. Access is possible if this information is presented in some good mark-up language such as SGML and difficult to impossible when presented as bit-mapped images or visually-formatted text.

More recently the SAP has begun exploring possible methods that permit good non-visual access to information conventionally presented as graphics.

1 Methods for Non-Visual Access to Graphical Information

There are a number of audio technologies that are useful as substitutes or enhancements for visual presentation of graphical information. Many of these technologies rely on feedback from the computer to identify and display information about the important objects in the figure.

It is found, for example, that blind people can "read" maps rather well by using a touch screen and running their fingers along a road or railroad track, interrogating cross streets as they are encountered, etc. (Jacobson, in press). This "map-reading" method requires two things:

1. The computer must have some means of disclosing to the viewer the objects at any given location, and

2. the blind person must be capable of assimilating a spatial image of where various objects lie on this map.

A common technique used to make assimilation of the figure easier is through use of a tactile image. Unfortunately there are no technologies for displaying refreshable tactile images on-line, but it has recently become possible to print a tactile figure, place this figure on a touch screen or other digitizing tablet, feel the tactile images, and receive audio feedback from the computer about those images.

The most convenient tactile printing technology is the TIGER TactIle Graphics EmbosseR (TIGER) developed in the SAP group. One can also print or copy a black and white image on "swell paper" (Swell), heat this special paper in a radiant heater, and obtain a tactile copy when the black areas swell.

Off-line printing is time-consuming and makes it very difficult for a blind person to take advantage of features like zoom views. A number of on-line haptic technologies are being explored motivated by various virtual reality uses. One such technology, the haptic mouse, has already been introduced or announced for imminent release by several companies (Immersion, Canada[1], Canada[2]). These devices should soon permit blind people to explore graphics on-line.

Another audio technology is use of non-speech audio to display visual images and other data (ICAD). The TRIANGLE application (TRIANGLE) and a new Windows 95 Accessible Graphing Calculator (ACG) both developed by the SAP uses tone plots to represent x-y graphs. The x axis is mapped to time and the y axis to a tone that is high for large y and low for small y. This provides a good qualitative overview of a graph. The SAP is currently investigating audio enhancements to provide more quantitative non-speech audio information such as beats with frequency proportional to the slope or second derivative of y with respect to x (Audio).

People with only moderate visual disabilities or people with good vision but various visual processing disorders (e.g. dyslexia) can achieve very good access by the combination of visual images reinforced by audio, and many are expected to find the haptic mouse useful as well.

The critical necessity for any of these methods to work is a well-structured data format that includes labels and permits other information about objects and the location of these objects in the figure.

2 Accessibility of bit mapped graphics on the WWW

A bit map image is essentially inaccessible, because the visual appearance can seldom be translated into an audio or a tactile image that is easily recognized by a person with a severe print disability.

The SAP has recently developed a relatively simple method that permits authors or editors to "make bit maps accessible" by adding identifying information related to objects in the figure. This procedure requires a current generation 4 Netscape or Internet Explorer browser and a screen reader that works with those browsers. An example (Example) is a campus map of Oregon State University. If the user clicks on the "accessibility link" adjacent to the bit map picture, the image is moved to the top frame of a double frame window. As the mouse pointer is moved from object to object, the label is displayed in the bottom frame. The screen reader automatically triggers on any change and reads the labels as they appear. The user may freeze the label by clicking on the object. This permits long or confusing labels to be browsed by the screen reader. Additional information may be linked from this window of course.

A blind user can explore the image with a touch screen instead of a mouse. Ideally she/he will have a tactile image on a digitizing pad. In the future it should be possible for a blind user to browse the picture on line with a haptic mouse. This access method works for a blind user even if the internet browser is set not to show pictures. With "no picture" enabled, the image will not appear in the top frame visually, but the labels still appear when the mouse pointer is placed where a particular object would be if it were visible.

Preparation of the information necessary to work in the accessibility link is relatively straightforward. The author or an editor must outline each object and write its label information. The only caveat is that authors must use the correct order for listing objects that overlap to be sure that the right one is on top.

The author/editor tools will be tested by Oregon State University faculty and staff and will be used to make a number of local and distance education courses more accessible beginning in Fall 1998. If these do prove very useful we will encourage their use in education more broadly.

3 VRML as a Graphics Language

The requirements that make information directly accessible in principle by blind people are basically the same as those that make information most usable by search engines, visualization routines, etc.

Virtual Reality Modeling Language (VRML) is a high-level well-structured language permitting very flexible modeling of three dimensional time-dependent interactive graphics. There are several research efforts aimed at making VRML more accessible by non-visual means (Toronto, NIST).

VRML may not be intrinsically fully accessible but it is a language capable of representing graphical information in a fully accessible form. To our knowledge there is no other common graphical language with this capability available at this time.

We have constructed several VRML examples (VRML) to illustrate graphical information common in physics education. We discuss the accessibility of each and how future developments could increase accessibility.

One example is an interactive display of electric potential along a line containing electric charges. The sign, magnitude, and position of the charges may be changed by the user.

Another example is a familiar picture from an elementary physics textbook illustrating friction on a block sliding down a tilted plane. This example is highly interactive, allowing the user to change the coefficients of friction, control the angle of tilt, etc.

The initial static pictures are quite accessible using technologies that are available today. Sighted viewers who want to see the labels can click on any object, and a dialogue box pops up and displays any information that the author has included about that object. The labels are included in nodes using a procedure similar to that used by Ressler et al. (NIST). If the user is also running a speech screen reader, it will normally speak the contents of this dialogue window, so the label will be both seen and heard.

A totally blind reader can print a tactile copy of the figure, place it on a digitizing pad, and then use her/his finger as the mouse to call up and hear the dialogue box provide information about objects. A deaf blind user can access the dialogue box with an on-line braille display.

We anticipate that haptic mouse developments are likely to make possible direct haptic access to these figures within a year or two. A combination of a static tactile picture and a haptic mouse could provide really excellent access to these examples. Feeling out a picture with a haptic mouse is tedious, so the tactile figure is good for a general overview. Then the mouse can be used to examine changes in the potential for example, or to detect the moment the block begins to slide as one changes some parameter.

The important information in the electric potential example could also be displayed in audio by the same technique used in the SAP Accessible Graphing Calculator (AGC). The advantage of an audio display is that the user can easily change something and then listen again. It would be tedious at best to read different figures by making tactile copies of each. This type of simple tone plot can also be displayed as a moving icon on a braille display for a deaf blind user. This technique is used in parallel with the tone plot in the TRIANGLE program.

The SAP is making several tools that permit audio display to be used conveniently with VRML figures. These tools include a user-controllable method for choosing objects to be displayed in a tone plot. The SAP is also making a simple authoring tool for x-y graphs in VRML. These data could be displayed in audio and examined quantitatively in the same display routine developed for the SAP Accessible Graphing Calculator. This plot browser provides excellent on-line audio or braille/haptic access to graphs. It can search for maxima, minima, inflection points, etc., and can speak the data values at any point.

It would not be difficult to extend this simple graphing tool to an almost arbitrarily rich and complex graph authoring environment with data, functional forms, and other types of information available to the viewer in both visual and alternate form.

VRML is a three dimensional modeling language, but at present there is no fully satisfactory way that a blind person can view 3D images. Commercial interests are likely to drive development of technologies for feeling virtual objects however. These could bring excellent access by people who are blind or dyslexic to properly prepared VRML graphics. We suspect that clever audio methods are possible that provide some degree of access even in absence of tactile hardware. There is much interest in spatially localized sound, and audio access to three dimensional displays by blind people could also become possible as a result. However all these access methods require that important objects be labeled.

Conclusion

We have demonstrated a "band-aid" approach to making current bit-mapped graphics files accessible. This method requires adding an object list to the original bit mapped image that relates the position of objects to their labels. These labels may be accessed in standard web browsers and spoken or displayed in braille by a standard screen reader.

We have also demonstrated several examples of accessible VRML graphics.

We intend to make authoring and editing tools available that allow others to produce label nodes for VRML objects and to create certain kinds of graphics (e.g. x-y VRML graphical data displays) that will automatically include all necessary information.

Most general VRML images can be made accessible in principle if the author takes the time to label objects so that they are accessible to the audio browser.

Full access to simple graphics (i.e. two dimensional time-independent displays) is possible now. Good access to more complex displays is possible in some cases with difficulty but requires development of better tactile or haptic hardware to permit really good access. Even in absence of such hardware however, we have demonstrated that clever users can achieve a degree of access that is almost beyond the imagination of most people today.

The major lesson of this research for computer scientists is that data visualization by people without vision is possible only if the data structures are high level and include adequate information. Visual appearance is generally inadequate to permit full identification of an object by people with visual disabilities, so explanatory labels are required. In addition the data structure and data display routines must relate the object to its position and vice versa. These properties are desirable in any case, because they greatly facilitate classification and search methods both present and future.

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TIGER, The TIGER TactIle Graphics EmbosseR, http://dots.physics.orst.edu/tiger_project.html

Swell, Major manufacturer of swell paper in the US is Repro-Tronics, Inc., 75 Carter Ave., Westwood, NJ 07675 http://www.repro-tronics.com

Immersion, Immersion Corporation, San Jose, CA, http://www.force-feedback.com.

Canada[1], Control Advancements, Kitchener, Ontario, CANADA, http://www.controladv.com

Canada[2], VisuAide, Longuauil, Quebec, CANADA

ICAD, International Conferences on Audio Display, http://www.santafe.edu/~kramer/icad/

TRIANGLE, TRIANGLE, a computer application enabling blind people to do math and science, http://dots.physics.orst.edu/triangle.html

AGC, Windows 95 Accessible Graphing Calculator http://dots.physics.orst.edu/agc.html

Audio, Audio graph research in the Science Access Project http://dots.physics.orst.edu/audiodisplay.html

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